METHOD AND DEVICE FOR GENERATING SHEET METAL MODEL FROM SOLID MODEL

BACKGROUND OF THE INVENTION

5   1. Field of the Invention

The present invention relates to a method and a device for generating a sheet metal model that can be unfolded automatically, from a solid model obtained by modeling a schematic solid shape of a sheet metal product,

10   by a simple operation in a three-dimensional sheet metal CAD/CAM system.

2. Description of the Prior Art

In the conventional three-dimensional sheet metal CAD/CAM system, a sheet metal model is usually generated

15   by one of the two methods explained as below. A first method is shown in Fig. 1. In this method, a so-called paper model having zero thickness as shown in (a) is generated first. Then, a sheet metal model as shown in (b) is generated by offsetting the paper model in the

20   thickness direction. This type of method for generating a sheet metal model is explained in Japanese unexamined patent publication No. 11-175575, for example.

A second conventional method for generating a sheet metal model is shown in Fig. 2. In this method, a base

25   portion (plane) of a sheet metal product is generated by using a plate model having a thickness as shown in (a) first. Then, a bending portion is added to an edge portion of the base portion so that the sheet metal model as shown in (b) is generated.

30   In the above-mentioned first conventional method for

generating a sheet metal model, there is a case where it is difficult to represent a shape of a sheet metal product having a thickness. For example, when generating side faces 101' and 102' of the sheet metal model by offsetting

5 two neighboring side faces 101 and 102 inward by a distance of thickness as shown in Fig. 3, an interference will be generated between the neighboring side faces 101' and 102'. In order to avoid this interference, it is necessary to keep a gap previously as shown in a portion

10 103 enclosed by a broken line. Such an operation is burdensome with some difficulty when the shape becomes complicated.

In addition, the above-mentioned second conventional method for generating a sheet metal model has a

15 disadvantage that it takes a long time for modeling a product. Moreover, if side faces 105, 106 and 107 that are bending portions from the base plane 104 are not perpendicular to the base plane 104 (i.e., if they are inclined planes) as shown in Fig. 4, it becomes difficult

20 to represent a shape of a sheet metal product. Namely, it becomes difficult to make a form of a joining portion between the neighboring side faces (e.g., side faces 105 and 106).

It is not desirable to force a designer to use a

25 special modeling method only for designing a sheet metal product under an environment where a three-dimensional CAD is commonly used for designing. If a three-dimensional CAD system that is mainly used for designing a solid model can be used for designing a sheet metal model that can be

30 unfolded automatically, in the same manner as a usual

machine component, the system will be accepted by designers easily.

SUMMARY OF THE INVENTION

5   An object of the present invention is to provide a method and a device for generating a sheet metal model that can be unfolded automatically, from a solid model obtained by modeling a schematic solid shape of a sheet metal product by an easy operation in a three-dimensional

10   sheet metal CAD/CAM system.

         According to one aspect of the present invention, a method for generating a sheet metal model is provided. The method is used for generating a sheet metal model that can be unfolded automatically, from a solid model obtained

15   by modeling an outer shape of a sheet metal product in a three-dimensional sheet metal CAD/CAM system. The method includes the steps of assigning entered attribution information including material and thickness of a sheet metal to a specified solid model, assigning entered

20   designation information for designating an open plane and a bending portion to the solid model, obtaining a minimum radius of curvature at the bending portion from the material and the thickness of the sheet metal, generating a downsized model defined by the designated open plane and

25   a plurality of planes that are generated by moving a plurality of planes of the solid model except the open plane inward in parallel by a distance that is a sum of the thickness of the sheet metal and the minimum radius of curvature, generating inner wall surfaces by moving a

30   plurality of surfaces of the downsized model except for

the open plane outward in parallel by a distance that is
equal to the minimum radius of curvature, generating plate
portions by a projection process in which the inner wall
surfaces are further moved outward in parallel by a
5   distance that is equal to the thickness of the sheet metal,
and generating a bending portion form that is a fillet
connecting neighboring plate portions at the bending
portion designated in the solid model.

In a preferred embodiment, a thickness input box and
10   a material selection pull-down menu are displayed as a
screen display for entering the material and the thickness
of the sheet metal, and an entered thickness value in the
thickness input box is used as a key for searching a
material master file so that one or more found materials
15   registered in connection with the entered thickness value
are listed in the pull-down menu.

According to another aspect of the present invention,
a sheet metal model generation device that constitutes a
three-dimensional sheet metal CAD/CAM system is provided.
20   The device includes a solid model generation portion for
generating a solid model by modeling an outer shape of a
sheet metal product, an attribution information assigning
portion for assigning entered attribution information
including material and thickness of a sheet metal to the
25   solid model, an open plane and bending portion designation
portion for assigning entered designation information for
designating an open plane and a bending portion to the
solid model, a minimum radius of curvature obtaining
portion for obtaining a minimum radius of curvature at the
30   bending portion from the entered material and thickness of

the sheet metal, a downsized model generation portion for generating a downsized model defined by the designated open plane and a plurality of planes that are generated by moving a plurality of planes of the solid model except the

5   open plane inward in parallel by a distance that is a sum of the thickness of the sheet metal and the minimum radius of curvature, a plate portion generation portion for generating inner wall surfaces by moving a plurality of surfaces of the downsized model except for the open plane

10 outward in parallel by a distance that is equal to the minimum radius of curvature and for generating plate portions by a projection process in which the inner wall surfaces are further moved outward in parallel by a distance that is equal to the thickness of the sheet metal,

15 and a bending portion form generation portion for generating a bending portion form that is a fillet connecting neighboring plate portions at the bending portion designated in the solid model.

In a preferred embodiment, the attribution

20 information assigning portion makes a screen display of a thickness input box and a material selection pull-down menu, uses an entered thickness value in the thickness input box as a key for searching a material master file so that one or more found materials registered in connection

25 with the entered thickness value are listed in the pull-down menu.

According to still another aspect of the present invention, a computer program product is provided that is installed in a computer that constitutes a three-

30 dimensional sheet metal CAD/CAM system. The computer

program makes the computer execute the process for
generating a sheet metal model including the steps of
assigning entered attribution information including
material and thickness of a sheet metal to a specified

5   solid model, assigning entered designation information for
designating an open plane and a bending portion to the
solid model, obtaining a minimum radius of curvature at
the bending portion from the material and the thickness of
the sheet metal, generating a downsized model defined by

10   the designated open plane and a plurality of planes that
are generated by moving a plurality of planes of the solid
model except the open plane inward in parallel by a
distance that is a sum of the thickness of the sheet metal
and the minimum radius of curvature, generating inner wall

15   surfaces by moving a plurality of surfaces of the
downsized model except for the open plane outward in
parallel by a distance that is equal to the minimum radius
of curvature, generating plate portions by a projection
process in which the inner wall surfaces are further moved

20   outward in parallel by a distance that is equal to the
thickness of the sheet metal, and generating a bending
portion form that is a fillet connecting neighboring plate
portions at the bending portion designated in the solid
model.

25   In a preferred embodiment, the computer program
makes a screen display of a thickness input box and a
material selection pull-down menu for entering a material
and a thickness of a sheet metal, uses an entered
thickness value in the thickness input box as a key for

30   searching a material master file so that one or more found

materials registered in connection with the entered thickness value are listed in the pull-down menu.

According to the method and the device of the present invention, a user can generate a sheet metal model
5   in a simple operation that can be unfolded automatically, from a solid model obtained by modeling an outer shape of a sheet metal product. As a result, man-hours necessary for generating a development in a design division and a process division can be reduced substantially.
10   According to the preferred embodiment, the user can save operation strokes and time for entering an attribution that is used for generating a sheet metal model. In addition, an input error, i.e., designation of a thickness and a material of a sheet metal that are not
15   registered as a possible combination can be avoided.

According to a computer program product of the present invention, the above-explained effects of the method and device can be obtained by installing the computer program into a personal computer or other
20   computers. Such a computer program can be supplied in a form stored in a computer-readable storage medium such as CD-ROM and is installed into a computer.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>
25   Fig. 1 shows a first conventional method for generating a three-dimensional sheet metal model by offsetting a paper model in the thickness direction.

Fig. 2 shows a second conventional method for generating a three-dimensional sheet metal model by adding
30   a bending portion to an edge portion of a base portion

represented by a plate model having a thickness.

Fig. 3 shows an example of a difficulty in generating a sheet metal model from a paper model.

Fig. 4 shows an example of a difficulty in
5 generating a sheet metal model by adding a bending portion to a plate model.

Fig. 5 is a block diagram showing a structure including a sheet metal model generation device in a CAD/CAM system according to an example of the present
10 invention.

Fig. 6 is a flowchart showing a procedure of generating a sheet metal model from a solid model in the example of the present invention.

Fig. 7 shows an example of a display window for
15 entering attribution information including a thickness and a material of a sheet metal in the example of the present invention.

Figs. 8A and 8B show examples of designation of an open plane and bending portions in the example of the
20 present invention.

Figs. 9A-9C show examples of generation of a downsized model, plate portions and bending portion forms.

Figs. 10A-10C show a concept of a data structure in the sheet metal model generated by the method according to
25 the present invention.

Figs. 11A and 11B show generation of a development from the sheet metal model generated by the method according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be explained more in detail with reference to embodiments and drawings.

Fig. 5 is a block diagram showing a structure
5   including a sheet metal model generation device in a
CAD/CAM system according to an example of the present
invention. A computer system that is used for a CAD
process in a CAD/CAM system is shown. This system is
constituted by installing a CAD program (software) into a
10   computer system such as a personal computer. The computer
system includes a central processing unit (CPU), a main
memory, an input device 11 such as a keyboard or a mouse,
a display device 12 such as a CRT or an LCD, an auxiliary
storage device 16 such as a hard disk drive, and a drive
15   device 14 for a removable storage medium.

A CAD program that constitutes the sheet metal model
generation device according to the present invention is
supplied in a form recorded on a removable storage medium
15 such as an optical disk (CD-ROM) and is installed into
20   the auxiliary storage device 16 via the drive device 14.
The CAD program installed in the auxiliary storage device
16 is loaded into the main memory and is executed by the
CPU. In the structure shown in Fig. 5, the CPU and the
main memory (the CAD program loaded into the main memory)
25   mainly constitute a CAD system, and a portion of the CAD
system that is related to generation of a sheet metal
model according to the present invention is shown as a
sheet metal model generation device 13 including
functional blocks.

30   The sheet metal model generation device 13 includes

a solid model generation portion 131, an attribution
information assigning portion 132, an open plane and
bending portion designation portion 133, a minimum radius
of curvature obtaining portion 134, a downsized model
5   generation portion 135, a plate portion generation portion
136, and a bending portion form generation portion 137.

   The solid model generation portion 131 has a
function of generating a solid model (like a block) by
modeling an outer shape of a sheet metal product using a
10   general feature having no attribution (such as a
thickness) of a sheet metal. This function is realized by
a general purpose three-dimensional CAD system.

   The attribution information assigning portion 132
has a function of assigning entered attribution
15   information including material and thickness of a sheet
metal to a specified solid model. The specified solid
model is a solid model that a user specifies as an object
of generating a sheet metal model among a plurality of
solid models including a solid model generated in the
20   above-mentioned solid model generation portion 131, a
solid model retrieved from the auxiliary storage device 16
and a solid model entered externally. Input of the
material and the thickness of a sheet metal is performed
as explained later.

25   The open plane and bending portion designation
portion 133 has a function of assigning designation
information entered by the user for designating an open
plane and a bending portion to the solid model in which
the outer shape of the sheet metal product is represented.
30   The designation information for designating an open plane

and a bending portion is necessary for generating a sheet metal model from a block-like solid model. The designation information includes information for designating an open plane in a real sheet metal product

5   and information for designating a portion in which a sheet metal is bent (i.e., a ridge line) in a real sheet metal product.

The minimum radius of curvature obtaining portion 134 has a function of obtaining a minimum radius of

10   curvature at the bending portion from the entered material and thickness of the sheet metal. This is obtained by searching a material master file 17 that is stored in the auxiliary storage device 16. Namely, the material master file 17 includes information of the minimum radius of

15   curvature that was defined previously in accordance with materials and thickness values. However, it is possible to obtain the minimum radius of curvature by calculation from a thickness and a coefficient that indicates the susceptibility of a material to bend.

20   The downsized model generation portion 135 has a function of generating a downsized model defined by the designated open plane and a plurality of planes that are generated by moving a plurality of planes of the solid model except the open plane inward in parallel by a

25   distance that is a sum of the thickness of the sheet metal and the minimum radius of curvature. This downsized model is a solid model smaller than the outer shape of the sheet metal product by a sum of the thickness and the minimum radius of curvature except for the open plane.

30   The plate portion generation portion 136 has a

function of generating inner wall surfaces by moving a plurality of surfaces of the downsized model except for the open plane outward in parallel by a distance that is equal to the minimum radius of curvature, and generating

5   plate portions by a projection process in which the inner wall surfaces are further moved outward in parallel by a distance that is equal to the thickness of the sheet metal. This plate portion has the above-mentioned inner wall surface, an outer wall surface obtained by moving the

10   inner wall surface further outward in parallel by a distance that is equal to the thickness, and filling matter between the inner wall surface and the outer wall surface. Therefore, the plate portion has a thickness.

The bending portion form generation portion 137 has

15   a function of generating a bending portion form that is a fillet connecting neighboring plate portions (end surfaces thereof) generated as explained above, at the bending portion designated in the solid model. This fillet can be generated as an extruded member of sector shape defined by

20   the minimum radius of curvature, the radius larger than the minimum radius of curvature by the thickness and end faces of the neighboring plate portions.

Fig. 6 is a flowchart showing a procedure of generating a sheet metal model from a solid model in the

25   example of the present invention. This procedure corresponds to a procedure for the CPU of the sheet metal model generation device 13 to execute in accordance with a computer program. It also corresponds to a procedure for each portion of the above-mentioned sheet metal model

30   generation device 13 to perform as a whole.

In the step #101, a solid model is designated. This
is a process in which the user specifies as an object of
generating a sheet metal model among a plurality of solid
models including a solid model generated in the above-

5   mentioned solid model generation portion 131, a solid
model retrieved from the auxiliary storage device 16 and a
solid model entered externally.

In the next step #102, the entered attribution
information including material and thickness of a sheet

10   metal is assigned to the above-mentioned specified solid
model. Input of the material and the thickness of a sheet
metal is performed as below, for example.

Fig. 7 shows an example of a display window for
entering attribution information including a thickness and

15   a material of a sheet metal in the example of the present
invention. This input display window 20 includes a
thickness input box 21 and a material selection pull-down
menu 22. When the user enters a desired thickness value
(2 mm in the illustrated example) in the thickness input

20   box 21, the attribution information assigning portion 132
searches a material master file 17 stored in the auxiliary
storage device 16 by using the thickness value as a key.
When one or more materials registered in connection with
the entered thickness value are found as a result, the

25   materials are listed in the material selection pull-down
menu 22.

When the user clicks the triangular mark 22a at the
right side of the material input box by using a pointing
device, a pull-down menu 22 listing the above-mentioned

30   materials appear. In the illustrated example, stainless

steel (SUS) and aluminum (AL) are listed in the pull-down
menu 22. The user can select a desired material from the
listed materials. In this way, the user can save
operation strokes and time for entering an attribution.

5   In addition, an input error, i.e., designation of a
thickness and a material of a sheet metal that are not
registered as a possible combination can be avoided.

     With reference to Fig. 6 again, an open plane and a
bending portion are designated, and the designation

10   information is assigned in the step #103. Figs. 8A and 8B
show examples of designation of an open plane and bending
portions in the example of the present invention. In this
example, the sheet metal model to be generated is a box
having a rectangular shape, in which one of six planes

15   (the bottom plane in the illustrated example) 25 is an
open plane. For example, the bottom plane becomes a
designated state when the user clicks a point around the
middle portion of the bottom plane of the solid model by
using a pointing device. For example, a display color of

20   the bottom plane is changed for informing the user that it
is selected. The selected bottom plane is shown with
hatching in Fig. 8A.

     In addition, each of the selected four bending
portions (four ridge lines) is shown with a mark "×" in

25   Fig. 8B. In the real embodiment, a color of the selected
bending portion (ridge line) is changed for distinguishing
from other lines so that the user can see that the bending
portion is selected. For example, a pointing device is
used for clicking the four sides of the upper plane of the

30   solid model one by one so that the four bending portions

are selected.

In the next step #104, a minimum radius of curvature at the bending portion is obtained. As explained above, a value of the minimum radius of curvature corresponding to

5   the material and the thickness is obtained from the material master file 17 stored in the auxiliary storage device 16. Alternatively, the minimum radius of curvature is calculated from the thickness and a coefficient that indicates the susceptibility of a material to bend.

10   In the next step #105, a downsized model is generated. The downsized model is a solid model defined by a plurality of planes that are generated by moving a plurality of planes of the solid model representing an outer shape of the sheet metal product inward by a

15   distance that is a sum of the thickness of the sheet metal and the minimum radius of curvature. However, the open plane that was designated in the step #103 is used as it is without being moved inward. This process is shown in Fig. 9A. The original solid model 27 is shown by a broken

20   line, while the downsized model 28 is shown by a continuous line. In the illustrated example, the bottom plane 25 of the original solid model 27 is an open plane, and other five planes are moved inward by a distance that is a sum of the thickness of the sheet metal and the

25   minimum radius of curvature so that the downsized model 28 is generated.

In the next step #106, the plural planes (five planes in the illustrated example) except for the open plane of the downsized model 28 are moved outward in

30   parallel by a distance of the minimum radius of curvature,

so that the inner wall surfaces are obtained. In the next

step #107, the inner wall surfaces are further moved

outward in parallel by a distance of the thickness of the

sheet metal as a projection process, so that the plate

5   portions 31-35 are generated. This series of processes is

shown in Fig. 9B. As a result of the above-mentioned

series of processes, an upper plate 31 and four side

plates 32-35 having the designated thickness are generated.

There is a gap that is determined by the minimum radius of

10   curvature between the upper plate and each of the side

plates, as well as between neighboring side plates.

In the final step #108, bending portion forms are

generated. This bending portion form means a fillet that

connects neighboring plate portions. This state is shown

15   in Fig. 9C. There is generated a bending portion form 36

that connects the upper plate 31 to the first side plate

32 (end surfaces thereof). In the same way, there are

generated bending portion forms 36-39 that connect the

upper plate 31 to the other side plates 33-35,

20   respectively. Furthermore, the bending portion form

(fillet) is generated only at the bending portion that was

designated in the step #103. Therefore, in the

illustrated example, the bending portion form is not

generated between the neighboring side plates. At this

25   portion, a butt form is generated in which one of the end

surfaces of the side plates is extended to the surface of

the other side plate. Generation of this butt form is not

relevant directly to the present invention, so the detail

explanation thereof is omitted.

30   A concept of a data structure in the sheet metal

model generated by the process explained above is shown in Figs. 10A-10C. Fig. 10A shows an object that is obtained by removing the side plates 33 and 35 and the bending portion forms 37 and 39 from the sheet metal model shown in Fig. 9C, which is turned upside down (rotated by 180 degrees). Fig. 10B shows an exploded view, in which the upper plate 31, the side plates 32 and 33, and the bending portion forms 36 and 38 are separated. Fig. 10C shows the sector cross section of the bending portion form 36, the minimum radius of curvature r and the thickness d of the sheet metal.

As understood from Fig. 10B, the sheet metal model that is generated by the method of the present invention is made of a plurality of plates having a thickness of d, and a plurality of bending portion forms (fillets) having a sector cross section at the bending portions. The bending portion form (fillet) is generated by an extrusion process in which a sector cross section that is defined by the minimum radius of curvature (r), the radius (r + d) that is the minimum radius of curvature plus the thickness (d) and a bending angle (90 degrees in the illustrated example) is moved in parallel by the distance (length) of the ridge line of the designated bending portion (L in Fig. 10B).

The sheet metal model having a constant thickness d that is generated by the method explained above can be unfolded automatically by a known unfolding method. This state is shown in Figs. 11A and 11B. The sheet metal model 40 shown in Fig. 11A is unfolded so that a developed view 41 is generated as shown in Fig. 11B.

While the presently preferred embodiments of the present invention have been shown and described, it will be understood that the present invention is not limited thereto, and that various changes and modifications may be

5   made by those skilled in the art without departing from the scope of the invention as set forth in the appended claims.